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# (54) Expiratory valve

(57) An expiratory valve for a pilot's face mask comprises a non-return valve (2) coupled to a pressure-biased valve (3) the non-return valve comprising a disc-like roof portion (16) supported by a plurality of arcuate ribs (17) defining an annular inlet through which breathing gas flows in a radial direction and which is closed by an annular resiliently flexible diaphragm (19) which sealingly engages the roof portion (16) with its inner edge (22). The pressure-biased valve (3) is of light weight to function under high G forces and comprises an annular valve seat (14) and a cooperating valve plate (45) secured to an annular resilient bellows member (47) in which a biasing pressure is established through tube (36) connected to a pilot's air supply.

FIG.3

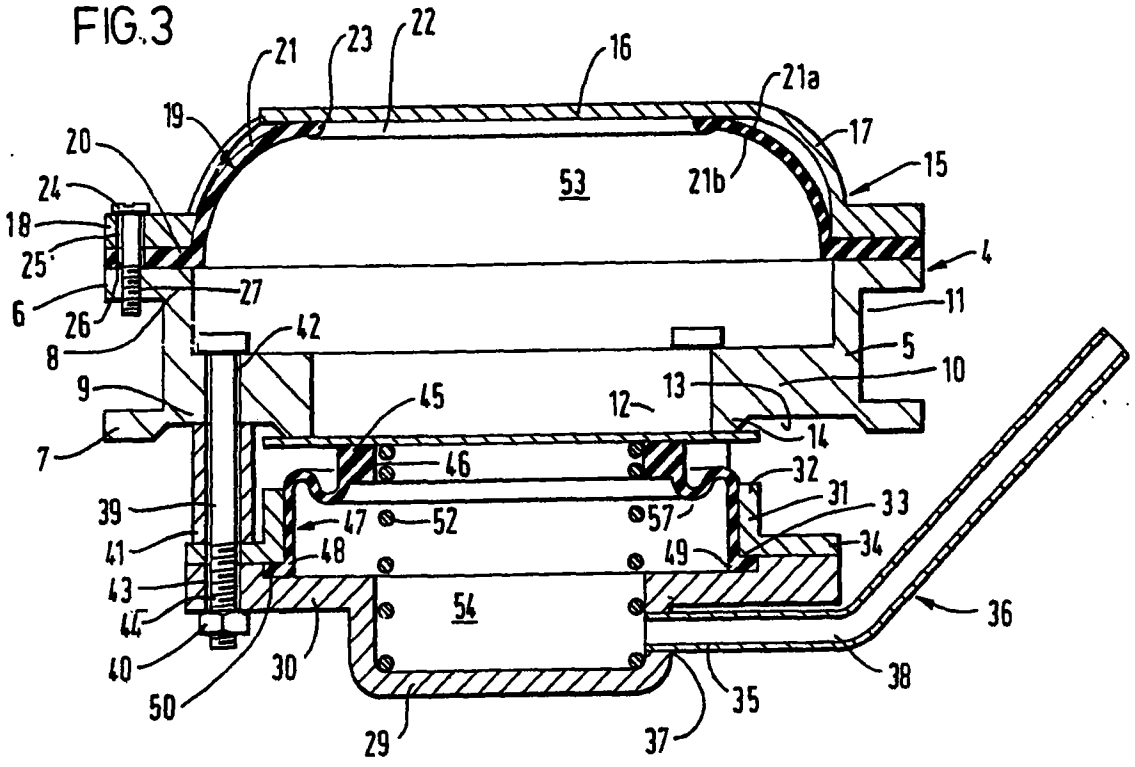




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FIG. 1

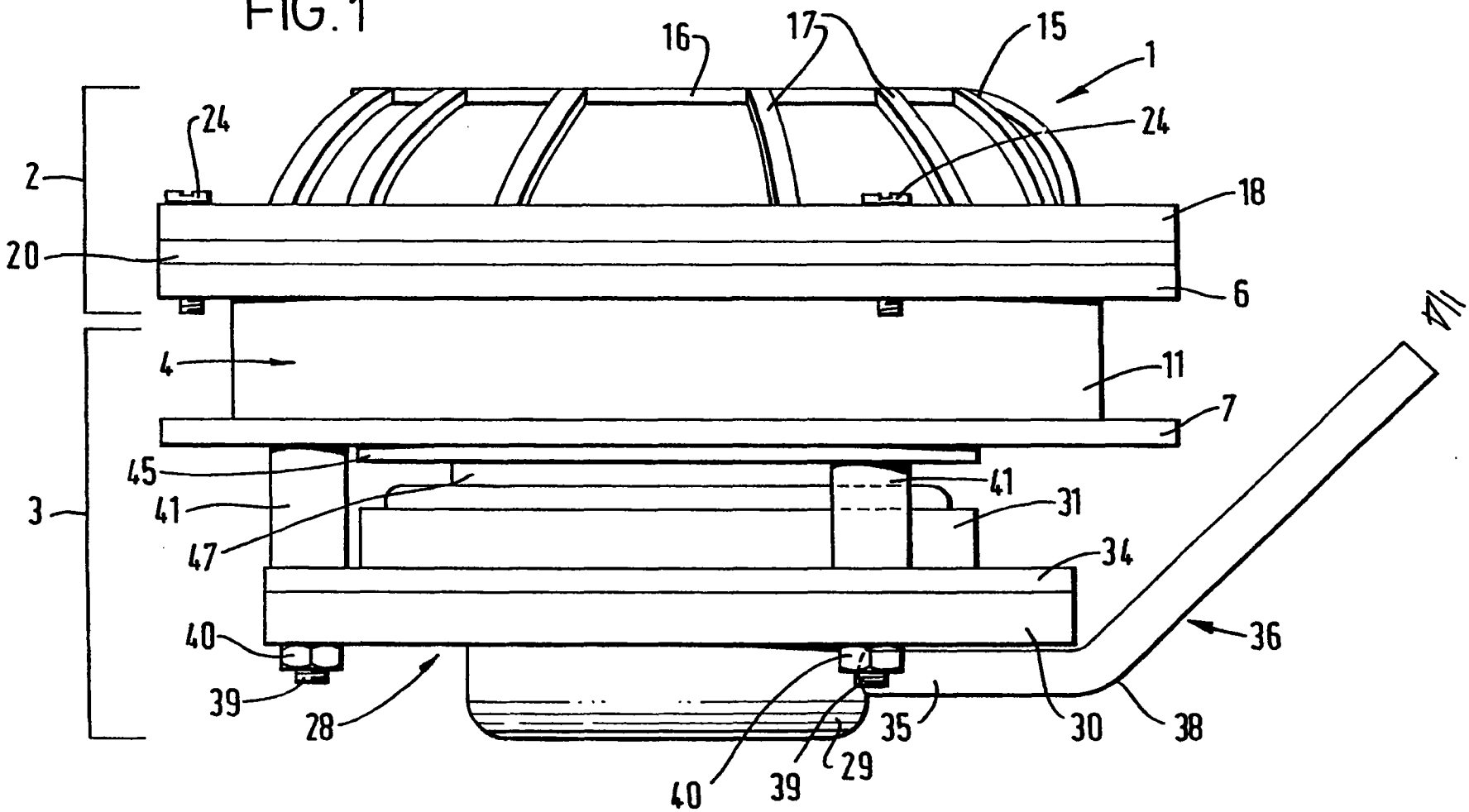
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FIG. 2

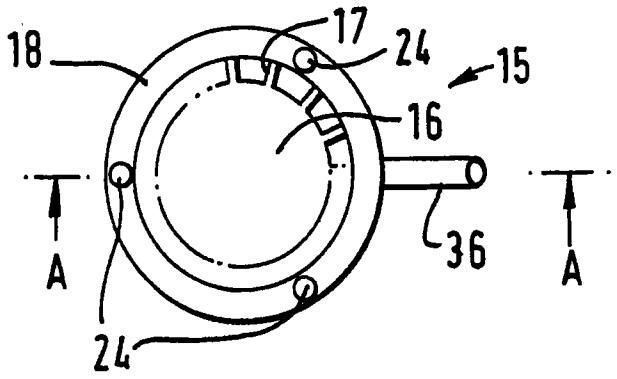


FIG. 5

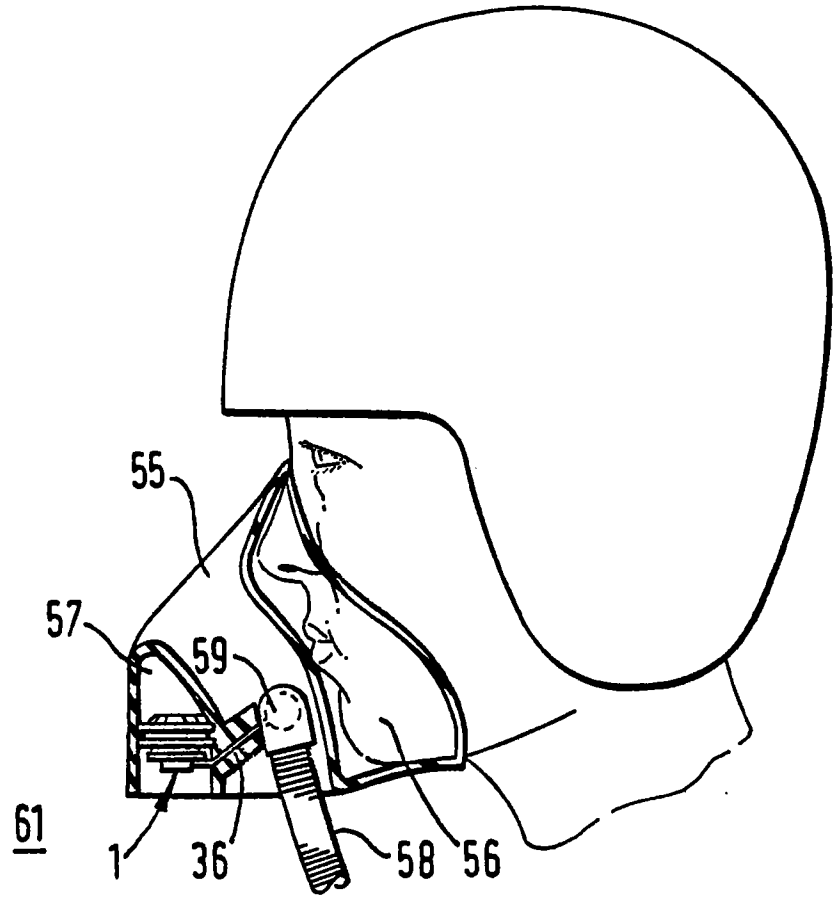

FIG.3

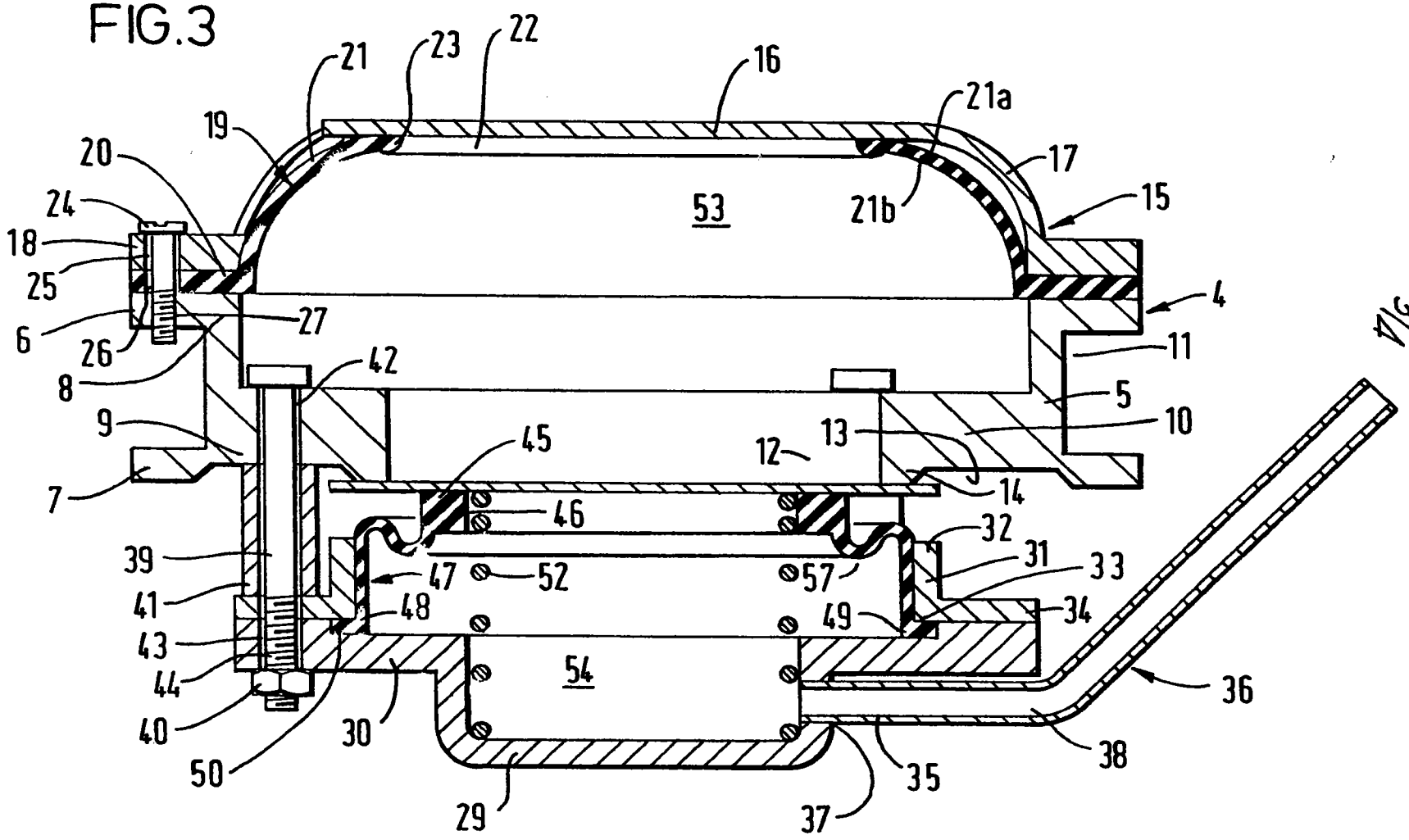
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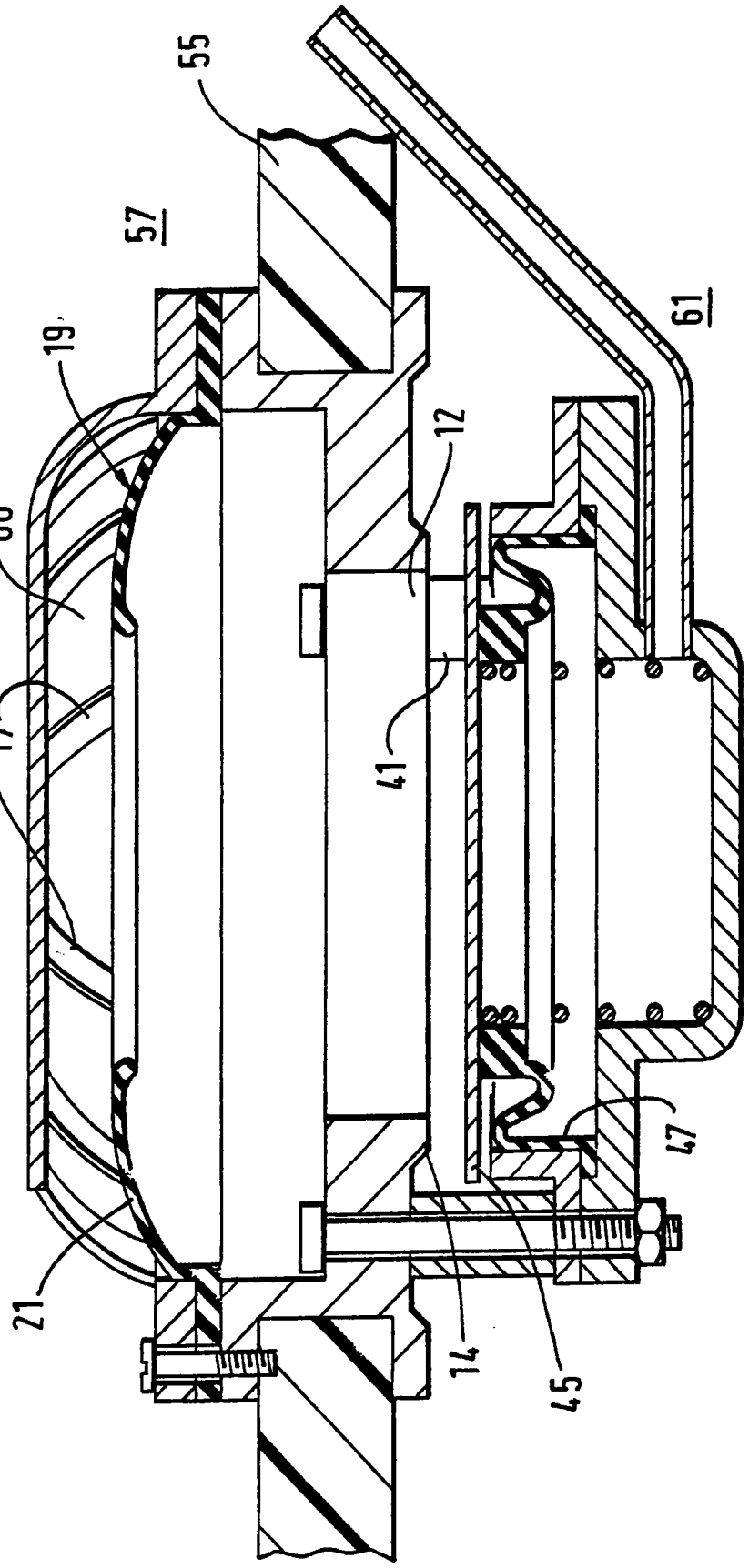
FIG. 4



# VALVE ASSEMBLY AND PARTS THEREFOR

## DESCRIPTION

This invention relates to a valve assembly and more particularly to a compensated expiratory valve assembly for aircrew breathing apparatus. The invention also relates to a one-way valve for use as part of such an assembly or independantly thereof and a valve diaphragm for use therewith.

In recent years the development of "fly-by-wire" systems has led to the appearance of a number of inherently unstable, but nevertheless controllable, combat aircraft. This instability results in aircraft having much greater manouvreability than has heretofore been acheived. However, with the increase in manouvreabiliy has come an increase in the stresses imposed on both crew and equipment by the forces generated during high speed turns etc.

A common feature in most modern combat aircraft is that the crew accomodation is not pressurised and breathing gas is therefore supplied individually to face masks worn by the crew members. The breathing gas is pressurised and is drawn into each mask through a

non-return valve therein as the crew member inhales. When the crew member exhales a second valve, called the expiratory valve, allows the exhalate to be vented to atmosphere. It is essential that this second valve only opens when the crew member exhales and to this end it is conventionally provided with a valve plate biased against its seat by a portion of the breathing gas which acts on a diaphragm, coupled to a annular valve plate support member. Another requirement of these valves is that they remain closed if the pressure of the breathing gas supply should fall below that of the ambient atmosphere. Therefore, the valve plate is floating and additionally biased closed by a spring between it and the diaphragm, giving a non-return type action.

It has recently become apparent that conventional expiratory valves as described above are not suitable for sevice in modern inherently unstable aircraft, because during manouvres which generate forces in excess of about 9G they are either forced open, allowing breathing gas to vent directly from the supply to atmosphere, or closed, making it impossible for the crew member to exhale. Both situations cause distress to the crew member and impair operational efficiency.

It is ,therefore, an aim of the present invention to provide an expiratory valve assembly which overcomes or substantially reduces the aforementioned problems.

According to one aspect of the invention, there is provided a a compensated expiratory valve unit comprising a body with an outlet including a valve seat, a valve closure member attached to a moulded cup shaped resilient member normally biased against said seat to make a seal therewith, a first chamber in the body upstream of the outlet having an inlet thereto normally closed by a non-return valve, said first chamber venting to the exterior of the body when the valve closure member is lifted off its seat, and a second chamber downstream of the valve closure member with an inlet thereto for the admission of a compensating fluid pressure, the arrangement being such that if the pressure in the second chamber drops to a level that results in the valve closure member being lifted from its seat, any fluid pressure admitted to the first chamber via the outlet thereto will close the non-return valve.

Preferably, the second chamber is partially defined by said resilient member and the outside diameter of said moulded resilient member where it is attached to the

valve closure member is less than the inside diameter of said valve seat.

In a preferred embodiment the moulded resilient member includes a first annular portion of a first diameter, a second annular portion of a second smaller diameter and a shoulder portion joining said first and second portions. Conveniently the moulded shoulder has a re-entrant S-shaped radial cross-section and the wall thickness of said second annular portion is greater thant that of said first annular portion.

In the preferred embodiment the valve closure member is a plate which is attached to the resilient member by means of an adhesive. It may however be fused thereto during moulding of the resilient member.

The natural resilience and shape of the resilient member will normally ensure that it closes against the valve seat. However, a spring maybe located coaxially within said resilient member to such closing as a safety measure.

According to another aspect of the invention, there is provided a non-return valve assembly comprising a valve body having an annular inlet thereto normally closed by

a flexible cup-shaped sealing diaphragm attached thereto, said diaphragm being normally biassed to engage with the body to make a fluid tight seal therewith and occlude the inlet.

Preferably, only a part of the diaphragm with the body only a part of the diaphragm engages with the body to make said fluid tight seal. In the preferred embodiment, the cup-shaped diaphragm has a central hole therein, the perimeter portion around said hole providing the part which makes the fluid tight seal.

Preferably, the diaphragm has a base with an annular laterally extending flange therearound by means of which the diaphragm is secured to the valve body, said body including a roof portion axially spaced from said flange and with which the perimeter region of the diaphragm cooperates to make said fluid tight seal. Conveniently, the diaphragm is provided with a bead around the central hole on its face remote from the roof portion of the body.

A plurality of ribs maybe provided to extend across the annular inlet to contain the diaphragm within the body when a fluid pressure is applied thereto. In the preferred embodiment, the roof portion is planar and

supported by the ribs in axially spaced relation with the remainder of the body, the curved portion of the diaphragm between the central hole and the flange arounds its base being operable to occlude the inlet and the perimeter portion of the diaphragm around the central hole being planar.

According to a still aspect of the invention, there is provided a valve diaphragm for a non-return valve comprising a dish-shaped annular body portion surrounding a central aperture, and attachment means extending laterally from said annular portion at a location non-coplanar with the central aperture. Preferably, the attachment means comprises an annular flange extending from the base of the annular body portion and in the annular body portion is curved in cross section. The annular body portion could however have other cross sections.

In the preferred embodiment, the upper region of the annular body portion adjacent the central aperture is ceplanar and coplanar with the central hole. Conveniently, the annular body portion has an inside an inside and outside surface and an annular bead is formed around said inside surface around the central aperture.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a side view of a valve assembly of the present invention,

Figure 2 is a plan view of the assembly of Figure 1 invention,

Figure 3 is a sectional view taken along the line A-A of Figure 2 with the valve unit in its closed condition,

Figure 4 is a sectional view taken along the line A-A of Figure 2 with the valve unit in its open condition and

Figure 5 shows a crew member wearing a mask, partially cut away, incorporating the valve assembly of Figures 1 to 4.

Referring now to Figures 1-3, there is shown a compensated expiratory valve assembly 1 which comprises a non-return valve 2 and a pressure biased valve 3.

The valve unit 1 includes first body member 4 which comprises a ring-like portion 5 having first and second annular flanges 6 and 7 extending radially outwardly from first and second axial extremities 8 and 9 of the

ring-like portion 5. A third annular flange 10 extends radially inwardly from the second axial extremity 9. A rectangular section groove or channel 11 is defined about the first body member 4 between the first and second flanges 6 and 7 and the radially outer surface of the ring-like portion 5, the purpose of which will be explained hereafter. A central hole 12 is defined by the radially inner margin of the third annular flange 10. An annular channel 13 surrounds the hole 12 and is formed in a planar annular surface of the body member 4 defined by the second and third annular flanges 7 and 10 and the second annular extremity 9 of the ring-like portion 5. A valve seat 14 in the form of bead is formed by the surface of the first body member 4 between the central hole 12 and the annular channel 13 therein.

A flattened domical cap 15 comprises a disc-like roof portion 16 supported by a plurality of arcuate support members or ribs 17 extending radially inwardly and axially away from the radially inner margin of a peripheral radially extending flange 18. The spaces between the ribs 17 define an annular inlet to the domical cap. The peripheral flange 18 is annular and has similar radial proportions to the first flange 6 of the body member 4.

A resiliently flexible annular diaphragm 19, preferably moulded from a natural or synthetic rubber material, comprises a planar annular rim portion 20 and an annular body portion 21 which is accurate in cross-section and extends radially inwardly and axially away from the inner margin of the rim portion 20, and has a normally concave inner surface 21a and a normally convex outer surface 21b. A central hole 22 is defined by the radially inner margin of the diaphragm 19 , and has a diameter less than that of the roof portion 16 of the domical cap 15. A bead 23 is formed around the central hole 22 on the inner surface of 21a.

The planar rim portion 20 of the diaphragm 19 is clamped between the domical cap 15 and the first body member 4. The convex outer surface 21b of the diaphragm 19 immediately surrounding the central hole 22 normally rests sealably against the inner surface of the roof portion 16 of the domical cap 15 and is biassed into sealing engagement therewith due to the shape and natural resilience of the diaphragm 19. In this position, the diaphragm 19 occludes the annular inlet to the cap 15.

A plurality of screws 24 extend through holes 25 equally circumferentially spaced around the peripheral flange 18 of the domical cap 15, through coaxially aligned holes 26 in the planar rim portion 20 of the diaphragm 19 and threadably engage coaxially aligned holes 27 in the first flange 6 of the first body member 4 . The planar rim portion 20 of the diaphragm 19 is thus sandwiched betweem the peripheral flange 18 of the domical cap 15 and the first flange 6 of the first body portion 4 forming a fluid-tight seal between the planar rim portion 20 of the diaphragm 19 and the first annular flange 6 of the first body portion 4.

A second body member 28 comprises a hollow cylindrical boss portion 29 extending axially from the radially innermost margin of an annular flange portion 30. An annular element 31 comprises first and second axial extremities 32 and 33 and is provided with an annular radially extending flange 34 about the second axial extremity 33 thereof. The annular flange 34 of the annular element 31 has similar radial dimensions to the flange portion 33 of the second body member 28. The annular element 31 and the second body portion 28 are coaxially clamped together such that the boss 29 and the annular element 31 extend axially away from each other.

A first portion 35 of a tube 36 is sealingly received by an orifice 37 in the boss portion 29 and extends radially outwardly therefrom and parallel to the plane of the annular flange portion 30. The tube 36 has a bend 38 in it which is located beyond the the circumference of the annular flange portion 30 of the second body member 28. The tube 36 is bent towards the annular element 31 at an angle of approximately 45° to the line defined by the central axis of the first portion 35 of the tube 36.

First and second body members 4 and 28 and the annular element 31 are symmetrically disposed along a common axis such that the central hole 12 in the first body member 4 is directly opposite the first axial extremity 32 of the annular element 31. The body members 4 and 28 and the annular element 31 are held in their correct relationships by the combination of bolts 39, nuts 40 and tubular spacers 41. The bolts 39 extend through equally spaced holes 42 in the third flange 10 of the first body member 4 and through axially aligned holes 43 and 44 in the flange 34 of the annular element 31 and the annular flange portion 30 of the second body member 28. Each spacer 41 is located coaxially around a bolt 39 and between the first body member 4 and the flange 34 of the annular element 31.

A valve plate 45 is affixed and secured to a first portion 46 of an annular resiliently flexible member 47 and normally rests against the valve seat 14. The annular resiliently flexible member 47 has a second portion 48, of greater diameter and having a thinner wall, provided with a radially outwardly extending planar rim portion 49. A radially inwardly open annular slot 50 is defined on two sides by a step formation on the annular flange portion 30 of the second body member 26 and on one side by the annular flange 34 of the annular element 31. The planar rim portion 49 of the annular resiliently flexible member 47 is clamped in the annular slot 50. The annular resiliently flexible member 47 further comprises a portion of increasing diameter 51, connecting said first and second portions 46 and 48 thereof and having a re-entrant S-shaped radial cross-section. The annular resiliently flexible member 47 is moulded from a natural or synthetic rubber material. A helical spring 52 is located coaxially within the annular resiliently flexible member 47 between the valve plate 45 an the closed end of the boss portion 29.

Referring to Figures 3 and 5, a first chamber 53 is defined between the first body member 4 and the domical cap 15. A second chamber 54 is defined within the second body member 28, the annular resilient member 47 and the valve plate 45. The groove 11 accepts the rim portion of an orifice in the wall of a face mask 55 in order to secure the valve unit 1 in position therein . The mask 55 is positioned over the mouth and nose of a wearer 56. When the pressure in the interior 57 of the mask 55 is less than the pressure in the first chamber 53, the convex portion of the inner margin 23 of the annular diaphragm 19 is forced into contact with the inner surface of the roof portion 16 of the domical cap 15, under the action of the pressure differential and its own resilience, thus forming a circular seal against the flow of fluid from the mask interior 57 to the first chamber 53 and occluding the annular inlet to cap 15. The tube 36, which is connected to the wearer's supply of beathing gas 58, ensures the equalisation of the pressure in the second chamber 54 with the pressure of the breathing gas supply 58. The fluid pressure thus set up in the second chamber 54 combined with the resilience of both the annular resilient member 47 and the helical spring 51 produces a force biasing the valve plate 45 against the valve seat 14. In order not to unduly stress the wearer 56,

it is desirable that the outside diameter of the first portion 46 of the annular resilient member 47 is less that the internal diameter of the valve seat 14. It is important that the ratio between the diameter of the valve seat 14 and that of the first portion 46 of the annular resiliently flexible member 47 is chosen carefully. If the diameter of the first portion 46 of the annular resiliently flexible member 47 is too small with respect to that of the valve seat 14, the valve will tend to open at times other than during exhalation. If, however, the converse is the case the wearer 56 will find difficulty in opening the valve and breathing comfortably.

Referring also to Figure 4, when the wearer 56 inhales, breathing gas flows through a non-return valve 59, located in the wall of the mask 55, from the breathing gas supply 58 into the mask interior 57. Some of the gas then passes to the wearer's lungs while a portion remains in the mask interior 57. When the wearer 56 ceases to inhale the pressure across the non-return valve 59 equalizes and the flow therethrough comes to an end. As the wearer 56 exhales, the pressure in the mask interior 57 increases which initially causes the dished annular diaphragm 19 to flex into the first chamber 53 and away from the roof portion 16 of the

domical cap 15. This allows exhalate from the wearer 56 to flow radially into the first chamber 53 through apertures 60 between the support members 17. The pressure in the first chamber 53 thereby increases until the force on the surface of the valve plate 34 exceeds the bias force acting on the valve plate 45 in the other direction so the valve plate 45 is forced off of its seat 14 and the exhalate in the first chamber 53, and ultimately in the mask interior 57, is vented to atmosphere 61 through the central hole 12 in the first body member 4. The valve plate 45 returns to its seat 14 when the pressure in the first chamber 53 is insufficient to overcome the bias force.

Should, for any reason, the pressure of the breathing gas supply 58 drop below that of atmosphere 61, the valve plate 45 will be lifted from the valve seat 14 due to the pressure differential across the valve plate 45. However, since the interior 57 of the mask 55 is at substantially the same pressure as the breathing gas supply 58, the pressure differential across the annular diaphragm 19 will keep the non-return valve 2 closed. This ensures that the wearer 56 is never exposed to the atmosphere 61 and any hazardous elements therein.

Whilst the non-return valve 2 has been described

integrated with a pressure biased valve 3, it is envisaged that it could also be used either independantly thereof or integrated with diverse other known valves.

Furthermore, while in the embodiment described above the resilience of the annular resiliently flexible member 47 is supplemented with that of a spring 52, the use of the spring 52 is not essential for the correct operation of a valve unit according to the present invention. The spring 52 acts as a fail-safe should the annular resiliently flexiible member 47 become deformed such that it is unable to return to its normal condition without additional assistance. However, it is unlikely that this fault condition would occur in practice.

It is envisaged that the major solid components of the valve of the present invention, with the exception of the valve plate 45, will be moulded from a plastics material, although metal could be used. Likewise, although the valve plate 45 is preferably of metal, a rigid plastics material could usefully be used for this component. The disphragms 19 and 45 can be moulded from a natural rubber material or a synthetic rubber material such as polyisoprene or silicone.

It will be appreciated that the reduction in moving mass acheived in the valve assembly of the present invention, when compared with the prior art, will result in smaller forces tending to open or close the pressure biased valve during high speed manouvres.

CLAIMS

1. A compensated expiratory valve unit comprising a body with an outlet including a valve seat, a valve closure member attached to a moulded cup-shaped resilient member normally biassed against said seat to make a seal therewith, a first chamber in the body upstream of the outlet having an inlet thereto normally closed by a non-retun valve, said first chamber venting to the exterior of the body when the valve closure member is lifted off its seat, and a second chamber downstream of the valve closure member with an inlet thereto for the admission of a compensating fluid pressure, the arrangement being such that if the pressure in the second chamber drops to a level that results in the valve closure member being lifted from its seat, any fluid pressure admitted to the first chamber via the outlet thereto will close the non-return valve.

2. A compensated expiratory valve unit according to claim 1 wherein the second chamber is partially defined by said resilient member.

3. A compensated expiratory valve unit according to claims 1 or 2 wherein the outside diameter of said moulded resilient member where it is attached to the valve closure member is less than the inside diameter of said valve seat.

4. A compensated expiratory valve unit according to any one of claims 1 to 3 wherein said moulded resilient member includes a first annular portion of a first diameter, a second annular portion of a second smaller diameter and a shoulder portion joining said first and second portions.

5. A compensated expiratory valve according to claim 4 wherein the moulded shoulder has a re-entrant S-shaped radial cross-section.

6. A compensated expiratory valve unit according to claim 4 or claim 5 wherein the wall thickness of said

second annular portion is greater than that of said first annular portion.

7. A compensated expiratory valve unit according to any one of claims 4 to 6 wherein said valve closure member is secured to said second annular portion.

8. A compensated expiratory valve unit according to any preceding claim wherein a spring is located coaxially within said resilient member.

9. A compensated expiratory valve as claimed in any preceding claim wherein the valve closure member is a plate which is attached to the resilient member by means of an adhesive.

10. A compensated expiratory valve unit substantially as hereinbefore described with reference to the accompanying drawings.

11. A non-return valve assembly comprising a valve body having an annular inlet thereto normally closed by a flexible cup-shaped sealing diaphragm attached thereto, said diaphragm being normally biassed to engage with the body to make a fluid tight seal therewith and occlude the inlet.

12. A valve assembly as claimed in claim 11 wherein only a part of the diaphragm engages with the body to make said fluid tight seal.

13. A valve assembly as claimed in claim 12 wherein the cup-shaped diaphragm has a central hole therein, the perimeter portion around said hole providing the part which makes the fluid tight seal.

14. A valve assembly as claimed in claim 13 wherein the diaphragm has a base with an annular laterally extending flange therearound by means of which the diaphragm is secured to the valve body, said body including a roof portion axially spaced from said flange and with which the perimeter region of the diaphragm cooperates to make said fluid tight seal.

15. A valve assembly as claimed in claim 13 or claim 14 wherein the diaphragm is provided with a bead around the central hole on its face remote from the roof portion of the body.

16. A valve assembly as claimed in any one of the preceding claims wherein a plurality of ribs extend across the annular inlet to contain the diaphragm within the body when a fluid pressure is applied thereto.

17. A valve assembly as claimed in claim 16 wherein the roof portion is planar and supported by the ribs in axially spaced relation with the remainder of the body.

18. A valve assembly as claimed in any one of claims 14-17 wherein the curved portion of the diaphragm between the central hole and the flange arounds its base is operable to occlude the inlet.

19. A valve assembly as claimed in any one of claims 13-18 wherein the perimeter portion of the diaphragm around the central hole is planar.

20. A valve assembly substantially as herein described with reference to the accompanying drawings.

21. A valve diaphragm for a non-return valve comprising a dish shaped annular body portion surrounding a central aperture, and attachment means extending laterally from said annular portion at a location non-coplanar with the central aperture.

22. A valve diaphragm as claimed in claim 21 wherein the attachment means comprises an annular flange extending from the base of the annular body portion.

23. A valve diaphragm as claimed in claim 21 or claim 22 wherein the annular body portion is curved in cross section.

24. A valve diaphragm as claimed in claim 23 wherein the upper region of the annular body portion adjacent the central aperture is planar and coplanar with the central hole.

25. A valve diaphragm as claimed in any one of the preceding claims wherein the annular body portion has an inside and outside surface and an annular bead is formed around said inside surface around the central aperture.

26. A valve diaphragm substantially as herein described with reference to the accompanying drawings.

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